ASTR 240: Two-Element Interferometer Lab

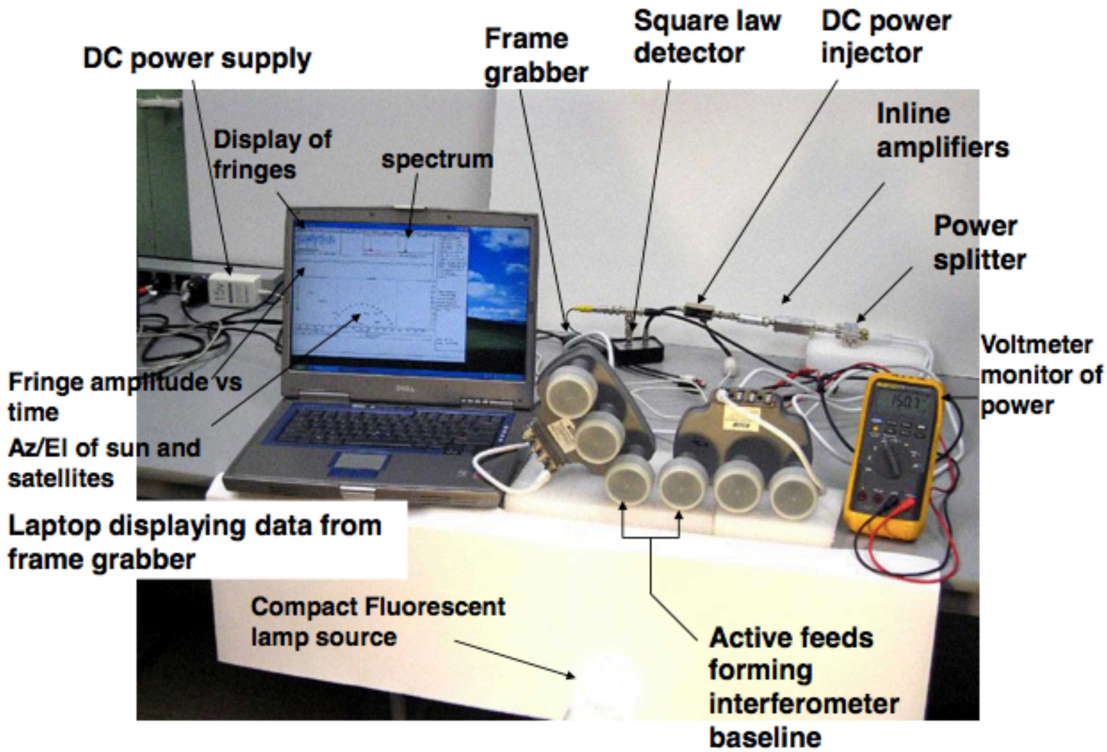

Fig. 1 – VSRT interferometer components

Exercise 1: Measuring the visibility function of a CFL

In this part of the lab, you will determine whether a CFL is best approximated as a point source, a uniformly illuminated disk, or a ring.

First, check to see which feeds on the triple-feed DirecTV receivers are active (do our active feeds match the active feeds in the picture?). You can determine which feeds are active by turning on one CFL, blocking the different feeds in turn, and looking for a response to the CFL on the laptop screen. When you have finished this part of the experiment, turn off the CFL.

Start with one CFL approximately 4 feet from the LNBFs, and the active feeds as close together as you can get them. Make sure that the CFL is as close to centered between the feeds as you can get it, and throughout the experiment try to keep the feeds pointed at the CFL. Before turning on the CFL, measure the following quantities: the size of the CFL (in as many dimensions as you think might be important), the distance from the CFL to the feeds, and the distance between the active feeds.

After you turn on the CFL, it might take a minute or so for the system to stabilize. Watch the interferometer response (the amplitude of the visibility) displayed on the laptop screen. The amplitudes will start off high and drop a bit during the first ~minute that the system is turned on. This is normal; just wait until they stabilize.

Record the interferometer response (the amplitude of the visibility) from the frame grabber on the laptop screen. The values will jump around a bit, so try to estimate a time average over a few seconds. You can also use the values to estimate the standard deviation of your measurements (which I will expect to see in the write-up). Gradually move the LNBFs apart, perhaps half an inch at a time, keeping the center line between the two feeds as close to centered on the bulb as possible. Record the interferometer response as a function of the distance between the LNBFs. Record the response out to a separation of at least 24 inches (the cables are six feet long, so this shouldn't be a problem). Try to avoid letting the cables dangle in front of the feeds. Also try to keep the feeds and bulb as close to the edge of the table as possible to minimize interference from the table.

When you are finished with this part of the exercise, turn off the CFL, and replace it with an incandescent bulb. Move the active feeds as close together as possible (the same distance as the shortest baseline you measured for the CFL). Measure the interferometer response, just for this shortest baseline length.

Some questions to consider in this part of the lab:

- Why is it important to keep the feeds pointed at the bulb? What would happen if they were pointed straight ahead, i.e., perpendicular to the line between them?
- How can you distinguish between the different possible geometries for the CFL bulb? Is it a point source, a uniformly illuminated disk, or a ring? If it is something other than a point source, how large is it, based on your interferometric measurements?
- How does the interferometer response to the incandescent bulb compare to that of a CFL of similar wattage? Why do you think this might be?

Analysis: Plot the interferometer response as a function of the separation between the LNBFs. Try fitting a point source, a uniformly illuminated disk, and a ring model to the data (for the disk and ring, you will have to fit for the best match to the size of the disk or ring). Look at the residuals to your fit. Are they significant? If so, what factors might be responsible for the residuals?

Exercise 2: Measure the separation of two CFLs using the interferometer

This part of the lab simulates how you might measure the separation between two sources in the sky using a variable-baseline interferometer.

Place the two bulbs approximately 4 ft from the LNBFs at the same height above the floor as the detectors. Place the bulbs about 4-5 inches from each other. Measure the distance from the LNBFs to the bulbs, as well as the distance between the two CFLs. Place the active feeds as close to each other as possible, and measure the distance between the feeds. As before, do your best to align the bulbs with the feeds, and to keep the two feeds centered on the bulbs as you increase the distance between them. Also keep the feeds pointed at the bulbs.

As before, increase the separation of the LNBFs in ~half-inch steps out to a separation of at least 24 inches. Record the average power and estimated standard deviation at each separation. (You should definitely see the first-order maximum in the visibility function, but measuring higher-order minima and maxima becomes more difficult.)

Some questions to consider in this part of the lab:

- Based on your measurements of distance between the bulbs and distance from the bulbs to the LNBFs, does the visibility function you measured reflect the wavelength of the radio wave that you expect?
- What is the theoretical distance to the first minimum for this wavelength (2.5cm) for this source separation and distance from the LNBFs, if the CFLs are approximated as point sources? If you discovered in Exercise 1 that the CFLs are not point sources, how might their geometry affect your answer?

Analysis: Plot the interferometer response as a function of the separation of the LNBFs. Try fitting the data as though the CFLs were represented by a double point source. What bulb separation do you measure? What do the residuals look like? Next, try improving your model using the results of Exercise 1. Do you measure the same source separation? Do the residuals improve?

Exercise 3: Measure the VSRT response to a double point source of variable width

This part of the lab is identical to the previous exercise, except that you should vary the separation between the bulbs while leaving the LNBFs fixed at a constant separation of a few inches (ideally the same as the separation between the bulbs in Exercise 2). Measure the interferometer response as you increase the separation of the bulbs by ~half-inch increments, keeping the center line between the bulbs aligned with the center of the LNBF feeds.

Questions to consider in this part of the lab:

- Do you expect the interferometer response in this exercise to be the same as the interferometer response you measured in Exercise 2? Why or why not?

Analysis: Plot the interferometer response as a function of the separation between the bulbs. Try to fit the data using the knowledge you have gained about interferometry. Consider the questions above. Why might the interferometer response be different when you vary the bulb separation, compared to when you vary the LNBF separation?

If you finish early: Measure the primary beam of an LNBF

Here's a bonus exercise for groups who finish early (it will help with the analysis of Exercises 2 and 3!). Use one CFL and one LNBF to measure the response of a single

LNBF as you move the CFL from a position directly in front of the feed off to the side. Use these measurements to estimate the size of the primary beam of the LNBF.

Consider some possible experimental design issues:

- What is the best way to move the CFL to measure the size of the beam? Should you move it on a plane parallel to the surface of the feed aperture, or keep a constant distance between the LNBF and the CFL?
- If you decide to keep a constant distance between the CFL and the LNBF, how can you measure the angle between the center of the LNBF and the CFL? If you move it along the parallel plane instead, can you estimate how much of the decrease in response is due to the primary beam of the LNBF compared to how much is due to the increasing distance between the LNBF and the CFL?

Lab writeup tips:

- Begin with a discussion of the theoretical background you will need to analyze the data in this lab.
- Describe the experimental setup and procedures (no need to go into great detail here; just describe the basics, and any modifications you made to the method described in this document or any problems you encountered).
- Present and describe the data you collected
- Describe your analysis procedures, including the process you used to fit the data and the likely explanations for any residuals that remain
- Include a discussion that addresses the "questions to consider" in each part of the lab
- Succinctly summarize your results and conclusions